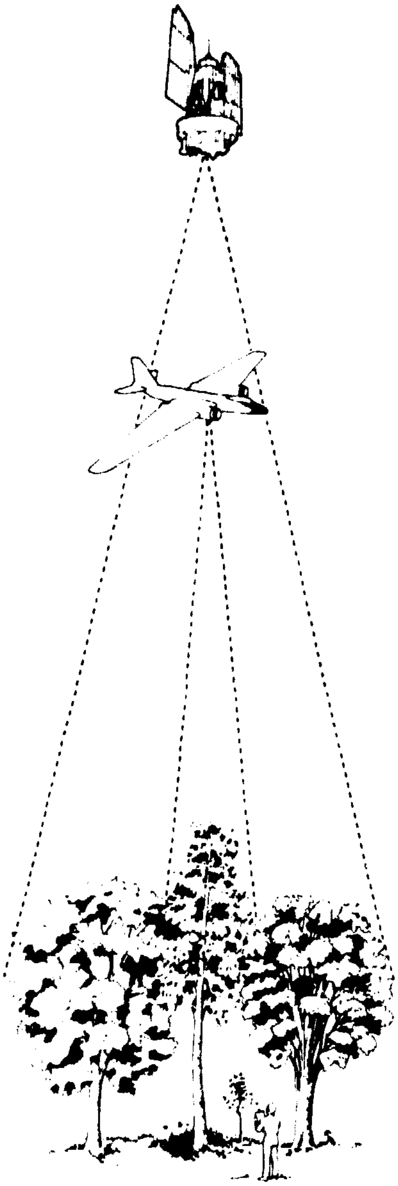
NATIONWIDE FORESTRY APPLICATIONS PROGRAM



RESULTS OF AN ANALYSIS OF THE UNCLASSIFIED PORTIONS OF THE SANDOVAL COUNTY, NEW MEXICO, TEST SITE

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PREFACE

The Ten-Ecosystem Study used remote sensing technology to classify forest, grassland, and inland water areas in Sandoval County, New Mexico. This site is characterized by extreme aridity, diverse topography, and a wide range of spectral reflectivity.

This report documents the results of a reanalysis of the site, which was conducted to determine whether the unclassified portions from the first study could be categorized. Data from the first study were reanalyzed using an unsupervised clustering algorithm. The results were categorized in an ecologically significant way using the National Land Classification System for Renewable Resources Assessments.

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ACRONYMS AND ABBREVIATIONS

ADP	automatic data processing
ELU	ecological land unit
Image 100	Interactive Multispectral Image Analysis System, Model 100
NLCS	National Land Classification System for Renewable Resources Assessments
NFAP	Nationwide Forestry Applications Program
pixel	picture element
TES	Ten-Ecosystem Study
USDA	U.S. Department of Agriculture

1. INTRODUCTION

1.1 BACKGROUND

The Ten-Ecosystem Study (TES) was designed to investigate the feasibility of using state-of-the-art automatic data processing (ADP) remote sensing technology to inventory forest, grassland, and inland water areas by administrative boundaries in the United States (ref. 1).

Sandoval County, New Mexico, was the fourth site in the TES and represented the pinyon pine and juniper association (ref. 2). The study for this site yielded high classification accuracies, generally from 90 to 100 percent (table 1-1, page 1-4), the same range of accuracy achieved for most of the other sites. In the original Sandoval County study, the site was divided into five classes, and area estimates for each of these classes were computed (table 1-2), including 9.12-percent forest, 6.13-percent grassland, 0.02-percent water, and 84.73-percent "other" (ref. 3). Because much of the site was not classifiable into definable categories, everything that was not forest, water, or grassland was placed into a "catch-all" grouping called "other." Considerable interest in identifying the composition of the "other" class developed because the other TES studies yielded low percentages of unclassified land while this study yielded high levels of unclassified land and high levels of classification accuracy.

Personnel of the TES project recently have been concerned with developing a more informative and useful scheme for structuring the results of the TES analyses than that originally proposed in the project plans. After considerable study, the National Land Classification System for Renewable Resources Assessments (NLCS) developed by Driscoll, Russell, and Meier (ref. 4) was recommended for future use by the Nationwide Forestry Applications program (NFAP). This system was also proposed recently for use in

inventory assessment and planning by the U.S. Department of Agriculture (USDA) Forest Service (ref. 5). The NFAP tested the NLCS classification on the Sandoval County test site to determine its applicability to remote sensing projects.

The NLCS is hierarchical in nature and derives its data from four sources: landform, soil, vegetation, and water elements. The data are structured in a natural way to develop ecological land units (ELU's), which become the working units of the scheme. These units can be combined as needed to aid in management planning or other Forest Service interpretive needs. The NLCS is especially useful because it allows the user to develop the system to suit his needs, yet later researchers can integrate the results of earlier work into studies of their own.

1.2 STATEMENT OF PROBLEM

This reanalysis study determined the composition of the Sandoval County test site using an unsupervised classifier to determine the component spectral classes of the study area. These classes were then ranked in an ecologically sound hierarchy. Tests for the accuracy of the classification were made using line transects across the site. Ground truth data were derived from the available aerial photography and supplemented by onsite inspection (ref. 6).

1.3 HYPOTHESES

To understand more completely the points of interest in this study, two hypotheses were tested:

a. The unclassified portions of Sandoval County can be identified.

b. The classes of the test site can be structured into an ecological context.

1.4 ASSUMPTIONS

This project was designed to be brief; therefore, the following assumptions were made:

a. This study would not be a test of the accuracy of the first Sandoval County study. Accuracy figures presented in the first study confirmed the precision of that work.

b. No registration of picture elements (pixels) would be attempted because of processing and time constraints.

c. Because there would be no registration, no pixel-by-pixel comparison would be attempted between classifications.

d. All analyses would be conducted between the computer classifications and the aerial photography and onsite inspections.

e. Only transect-type analyses of the classification accuracy would be attempted because there would be no registration.

TABLE 1-1.– SUMMARY OF TRAINING FIELD CLASSIFICATION ACCURACIES FOR THE SEPARABILITY AND INVENTORY STUDIES

Class	Separability study, percent			Inventory, percent (August)
	August	May	Temporal	
Softwood	99.5	99.7	100.0	100.0
Hardwood	77.6	100.0	100.0	100.0
Grassland	99.8	98.0	100.0	100.0
Water	100.0	100.0	100.0	100.0
Overall accuracy	94.2	99.4	100.0	100.0

TABLE 1-2.– CLASSIFICATION BREAKDOWN FOR SIMULATED INVENTORY

Class	Percent
Softwood	8.68
Hardwood	.44
Grassland	6.13
Water	.02
Other	84.73

2. METHODOLOGY

The test site reanalysis was performed in five parts:

Part 1 – An unsupervised classification of the site was developed using the Interactive Multispectral Image Analysis System, Model 100 (Image 100).

Part 2 – Background information on the vegetation in the test site was gathered for use in the development of the NLCS nomenclature. (Parts 1 and 2 were developed simultaneously.)

Part 3 – The resultant clustered outputs were compared with the previously interpreted aerial photography for the TES Sandoval County test site study and the TES computer analysis of Sandoval County.

Part 4 – A field analysis of any clusters that were not resolvable from photographic imagery was conducted. Also, a field verification of the unsupervised analysis was performed to determine the field accuracy of the unsupervised classification.

Part 5 – This final report constituted part 5 of the test site analysis.

3. DATA SOURCES

Whenever possible, data for this study were gathered from previously used sources and analyzed in standard ways to reduce time-consuming development tasks.

3.1 COMPUTER DATA SOURCES

Data for the study were derived from the original data set used in the first Sandoval County analysis. The Landsat scene for August 5, 1975, was converted for use on the Image 100. These data were not registered; therefore, the actual study site used in this analysis was similar to, but not identical with, the original 1000-by-1000 pixel study site used in the Parkhurst study (ref. 3).

3.2 NLCS HIERARCHY

To develop the NLCS hierarchy for use in the ecological structuring of the data, previous vegetational analyses of New Mexico were consulted. A final determination of the classification hierarchy was made from field observations.

3.3 FIELD ANALYSIS

Field work in Sandoval County was performed at the end of the analysis study to determine the field accuracy of the computer analysis. Five days were spent in various phases of the work. An overall survey of the site was made by carefully traveling all the major roads of the site. Then each community and each reference point were located, and their position and composition were determined relative to other points of reference and their composition. Transects were run from one known identifiable ground feature to another. Finally, apparent anomalous clusters on the printout were isolated and identified in the field, and the classes were field-verified. (See figure 3-1.)

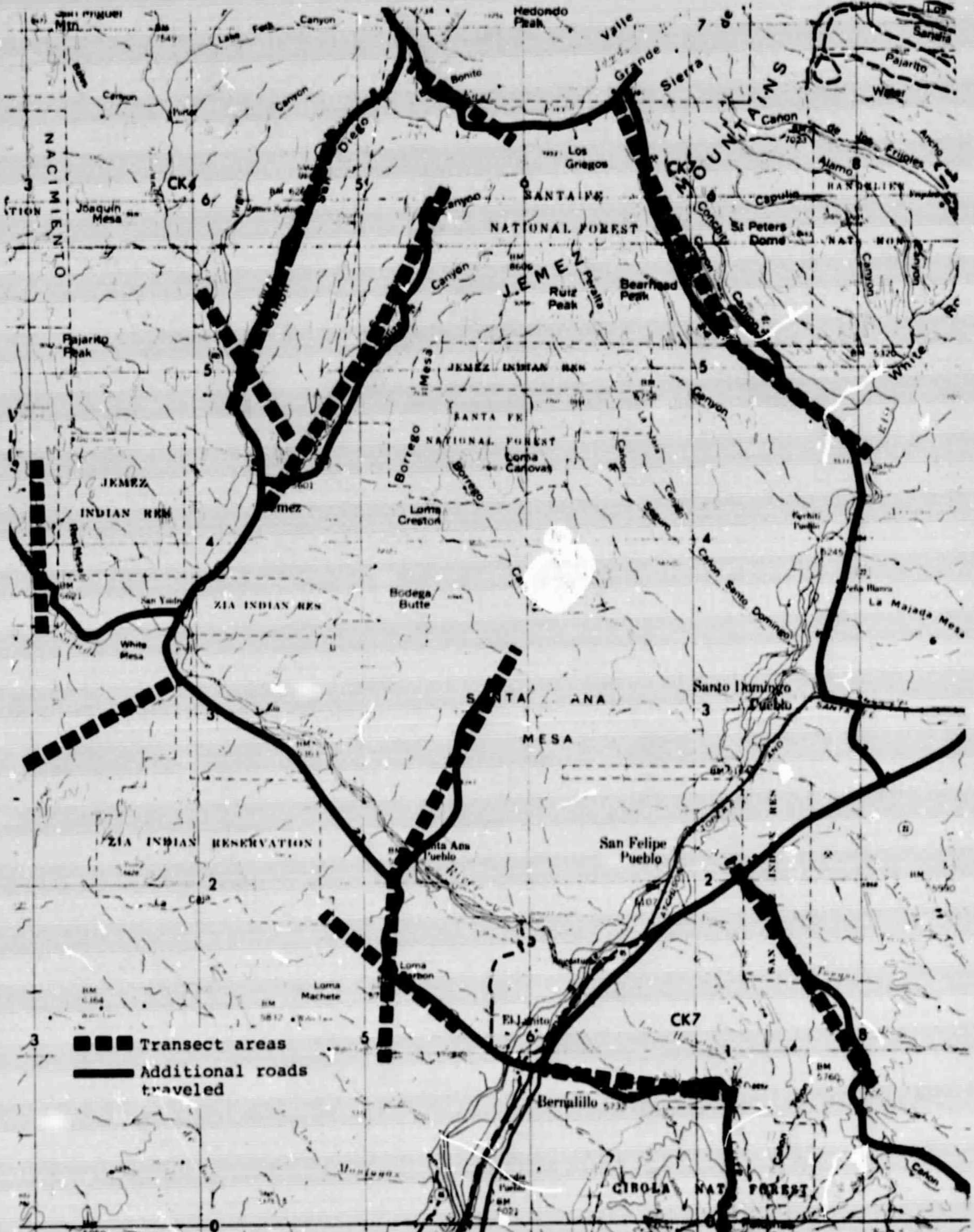

Figure 3-1.– Sandoval County test site, showing transect areas and additional roads traveled.

4. RESULTS

In this study, the unclassified portions of the site were identified, and a useful ecologically oriented classification was devised.

4.1 RESOLUTION OF THE "OTHER" CLASS

The primary purpose of this reanalysis was to identify the composition of the unclassified portions of the test site. Using the cluster algorithm of the Image 100 computer, data were split into 20 clusters; these were later combined into 10 classes and displayed. Table 4-1 presents the original 20 clusters; the 10 classes into which they were reduced; and the character symbol, number of pixels, percentage of the total site, total area, NLCS type, ecological class, and TES class associated with each of the reanalysis classes. Most of the original unclassified portions of the test site were reclassified into various forest, grassland, or shrub communities, which were then translated into some desired TES class. Two categories of bare rock were justifiably treated as "other" and account for about 12 percent of the site. They are essentially barren, with less than 5-percent vegetated surface.

Table 4-2 presents the inventory and separability results of the original study, as well as the results of this reanalysis study. It shows that the unclassified ("other") portion of the site was reduced from 85 percent for the inventory to 12 percent for the reanalysis.

4.2 NLCS HIERARCHY

Ten spectrally separable classes were produced in this study. With the exception of the rock classes, each of these is essentially equivalent to the association level commonly used

in plant ecology. The following sections contain a description and photograph of each class. (The entire map output will be published in the TES final report in early 1979.)

4.2.1 PONDEROSA PINE AND DOUGLAS FIR COMMUNITY

Three important trees and several minor elements characterize this community (fig. 4-1). The major trees are:

a. *Pinus ponderosa* (ponderosa pine)

b. *Pseudosuga taxifolia* (Douglas fir)

c. *Abies concolor* (concolor fir)

The minor elements include:

a. *Pinus flexilus* (limber pine)

b. *Populus tremuloides* (quaking aspen)

c. *Quercus gambelii* (Gambel oak)

d. *Acer negundo* (boxelder)

This community occurs primarily above a 2286-meter (7500-foot) elevation and is composed of the montane and mesa-top forests of the test site. These forests are dense, tall, and extensive, with many recreational activities and excellent timber potential.

4.2.2 MONTANE RIVER GALLERY COMMUNITY

This community (fig. 4-2) is associated with the ponderosa pine and Douglas fir community. However, it is decidedly wetter and follows all the permanent stream courses above 2286 meters (7500 feet). This class is separable from the first class by the presence of many deciduous hardwood trees. The primary elements of this community are:

a. *Pinus ponderosa* (ponderosa pine)

b. *Populus tremuloides* (quaking aspen)

c. *Acer negundo* (boxelder)

d. *Quercus gambelii* (Gambel oak)

e. *Salix nigra* (black willow)

f. *Populus sargentii* (cottonwood)

g. *Pseudosuga taxifolia* (Douglas fir)

h. *Abies concolor* (concolor fir)

These elements grow in a tangled mass along the stream courses throughout the higher elevations in the test site.

4.2.3 PINYON PINE COMMUNITY

Below the ponderosa pine and Douglas fir community, a dense pinyon pine community develops (fig. 4-3). This community has an essentially closed canopy with little bare soil showing. Its major elements include:

a. *Pinus edulis* (pinyon pine)

b. *Quercus gambelii* (Gambel oak)

The minor elements include:

a. *Juniperus deppeana* (alligator juniper)

b. *Juniperus scopulorum* (Rocky Mountain juniper)

c. *Juniperus monosperma* (oneseed juniper)

d. *Pinus ponderosa* (ponderosa pine)

This community is totally dominated by pinyon pine; vegetative elements from communities above and below occur with equal frequency. The pinyon pine community is usually found at elevations between 1981 meters (6500 feet) and 2286 meters (7500 feet); however, it occurs occasionally on higher exposed ridges.

4.2.4 PINYON PINE AND JUNIPER WOODLAND

This community (fig. 4-4) is related to the pinyon pine community (section 4.2.3). However, it has a higher percentage of juniper because of its lower elevation and drier moisture regime. The trees are spaced farther apart; therefore, the community is not totally closed.

The major elements include:

a. *Pinus edulis* (pinyon pine)

b. *Juniperus monosperma* (oneseed juniper)

c. *Juniperus deppeana* (alligator juniper)

This is the typical pinyon pine and juniper community known throughout the Southwest. It is spectrally different from other classes because of the increased percentage of bare soil and the abundant increase in the amount of juniper.

4.2.5 GRASSLAND AND JUNIPER COMMUNITY

A grassland and dispersed juniper community (fig. 4-5) has developed below the pinyon pine and juniper woodland. This community is dominated by grass, but it has a small and conspicuous juniper population that is invading the grasslands because of a lack of controlling fire and continuous overgrazing. Whether the community is ecologically discrete is open for debate. However, it is easily separable on physiognomic and spectral grounds. Also, it may have use in land management studies because it is an indicator of present and past land practices.

The major species in this community include:

a. *Juniperus monosperma* (oneseed juniper)

b. *Bouteloua gracilis* (blue grama grass)

c. *Hilaris mutica* (tobosa grass)

d. *Atriplex* (salt bush)

The minor elements include various weedy herbaceous invaders.

4.2.6 DESERT GRASSLAND

The desert grassland (fig. 4-6) is composed of a diversity of grasses, all of which are adopted to short growing seasons, extended droughts, hot summers, and cold winters. The composition of this grassland varies because of soil conditions and the amount of grazing pressure. Originally blue grama grass was dominant overall. However, overgrazing has caused it to decline, while many weedy herbs and grasses have increased. Now these less desirable plants dominate the formerly continuous grama grassland.

Species of the following genera are prevalent in this desert grassland:

a. *Bouteloua* (grama)

b. *Hilaria* (tobosa)

c. *Aristida* (three-awn)

d. *Stipa* (needle)

e. *Muhlenbergia* (muhly)

f. *Cenchrus* (sand bur)

g. *Bromus* (brome)

h. *Oryzopsis* (rice)

4.2.7 DESERT SHRUB COMMUNITY

The desert shrub community (fig. 4-7) is composed of a variety of shrub species that tend to grow in relatively pure stands.

These communities are most common on benches along some of the rivers and at the foot of many mesas and mountains. The class presented here is a physiognomic one based upon the shrub habit and does not represent the same ecological development.

Important components include:

a. *Atriplex canescens* (four-wing salt bush)

b. *Chrysothamnus naseosus* (rabbit brush)

c. *Artemisia* species (sage)

d. *Ephedra* species (Mormon tea)

e. *Yucca* species (soapweed)

f. *Opuntia imbricata* (cane cholla)

g. *Sarcobatus vermiculatus* (greasewood)

4.2.8 LOWLAND RIVERINE GALLERY COMMUNITY

Groves or galleries of trees have developed along the major river systems of the test site in otherwise desert areas (fig. 4-8). These communities are composed of several native and some introduced species. Generally, however, the major components include:

a. *Populus sargentii* (cottonwood)

b. *Salix* species (willow)

c. *Tamarisk* species (salt cedar)

d. *Celtis* species (hackberry)

e. *Ulmus* species (elm)

4.2.9 DARK BARE ROCK AND ERODED HILLS

This class usually occurs in the form of dissected, eroded hills composed of lava and red sandstone (fig. 4-9). The class is identifiable as dark unvegetated bare soil and rock.

4.2.10 LIGHT BARE ROCK

The second class of bare rock includes light-colored sand dunes, pumice outcroppings, and limestone (fig. 4-10). The class is identifiable as white or light, barren rock.

TABLE 4-1.– SUMMARY OF CLASSES DEVELOPED FOR REANALYSIS

Cluster	Class	Character symbol	Number of pixels	Percentage of total site	Total area per class, square hectometers (acres)	NLCS type	Ecological class	TES class
11 12 13 14 15 16 17 18 19	1	:	518 446 447 98 5 13 2 2 1	0.95	682 (1 685)	Light bare rock	Rock	Other
10	2	'	2 119	1.32	943 (2 331)	Lowland riverine gallery	Deciduous lowland gallery forest	Hardwood
9	3	=	17 713	11.03	7 885 (19 484)	Dark bare rock and eroded hills	Rock	Other
8	4	>	14 750	9.19	6 121 (15 125)	Grassland and juniper	Desert grassland	Grassland
7	5	/	31 014	19.32	13 806 (34 115)	Desert grassland	Desert grassland	Grassland
6	6	$	25 792	16.07	11 481 (28 371)	Desert shrub	Shrub community	Grassland
5	7	@	19 567	12.19	8 711 (21 524)	Pinyon pine and juniper woodland	Pinyon and juniper woodland	Softwood
3	8	*	13 281	8.27	5 912 (14 609)	Pinyon pine	Pinyon and juniper woodland	Softwood
1 2 20	9	A	167 6 019 7	3.85	2 679 (6 620)	Montane river gallery	Mixed montane river-bottom forest	Mixed hardwood and softwood
4	10	B	28 501	17.76	12 687 (31 351)	Ponderosa pine and Douglas fir	Montane conifer forest	Softwood

TABLE 4-2.- COMPARISON OF AUGUST SEPARABILITY, INVENTORY, AND REANALYSIS RESULTS

Class	August separability	Inventory	Reanalysis[a]
Softwood:			
Square hectometers	82 240	27 383	28 649
Acres	203 219	67 665	70 794
Percent	26.08	8.68	40.15
Hardwood:			
Square hectometers	2 593	1 390	2 283
Acres	6 407	3 435	5 641
Percent	.82	.44	3.25
Grassland:[b]			
Square hectometers	84 055	19 332	31 408
Acres	207 703	47 770	77 611
Percent	34.72	6.13	44.58
Water:			
Square hectometers	57	62	Not applicable
Acres	141	153	Not applicable
Percent	.02	.02	Not applicable
Other:			
Square hectometers	120 981	267 191	8 568
Acres	298 951	660 243	21 169
Percent	38.36	84.73	11.98
Total:			
Square hectometers	315 371	315 358	64 937
Acres	779 298	779 267	160 462

[a]These area results are not directly comparable because only every other line and element were sampled, and the data were not stretched or registered as was done in the original study.

[b]The term rangeland was used in the original study.

Figure 4-1.– Ponderosa pine and Douglas fir community. (This photograph also includes a large component of concolor fir.)

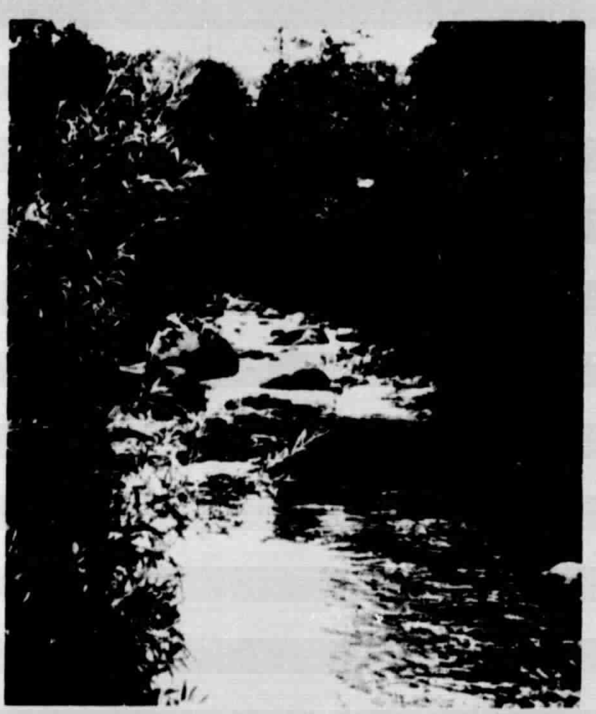

Figure 4-2.– Montane river gallery community. [This type of community develops at elevations above 2286 meters (7500 feet) along all the permanent water courses.]

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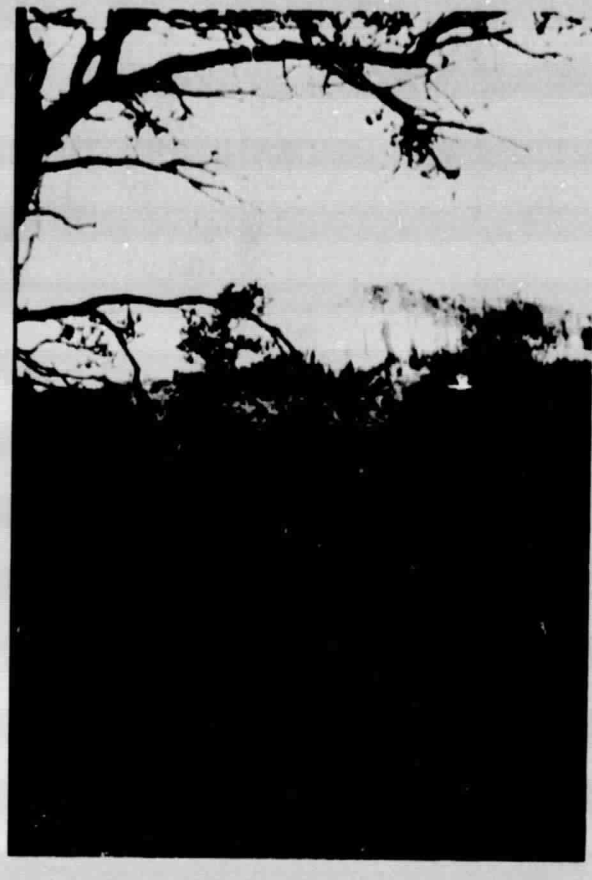

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Figure 4-3.– Pinyon pine community. (This community is characterized by a closed canopy and a predominance of pinyon pine.)

Figure 4-4.– Pinyon pine and juniper woodland. (An abundance of barren ground is evident in this photograph.)

Figure 4-5.– Grassland and juniper community. (This type of community occurs whenever junipers begin to invade the grassland.)

Figure 4-6.– Desert grasslands. (This community is typically overgrazed.)

Figure 4-7.– Desert shrub community. (This type of community is formed when the grassland is invaded by shrubs or shrub-like plants, in this case yucca.)

Figure 4-8.– Lowland riverine gallery community. [This type of community develops below an elevation of 2286 meters (7500 feet) along the major river systems.]

Figure 4-9.- Dark bare rock and eroded hills. (The composition of this class is primarily lava and sandstone.)

Figure 4-10.- Light bare rock. (This class is composed primarily of white sand and pumice.)

5. CONCLUSIONS

Two primary conclusions were drawn from this study:

a. Most of the "other" class defined by the TES procedures can be assigned to identifiable classes using an unsupervised clustering procedure.

b. Spectral classes derived from an unsupervised classifier can be placed into a useful, ecologically sound hierarchy.

3

6. REFERENCES

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